Annotations of *LSE* Research: Enhancing Accessibility and Promoting High Quality Biology Education Research

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HIGHLIGHTING THE ANNOTATIONS OF *LSE* RESEARCH FEATURE

Annotations of *LSE* Research is a project through which biology education researchers comment on articles from *LSE*, highlighting how each study was conceived, designed, conducted, interpreted, and reported, while also emphasizing the practical applications for biology teaching and learning that emerge from the work (Dolan, 2017). These annotations were originally designed to be a resource for individuals who are new to biology education research, but the annotations are helpful and informative for novice and expert investigators alike. This commentary aims to encourage all *LSE* readers to visit the evolving Annotations of *LSE* Research collection frequently, recommend it to colleagues, and use it to help trainees gain insights about the underlying architecture of biology education research studies and their publication.

We describe herein the history and approach of the annotations, as well as three frameworks that can be used to categorize the scope and methodologies in the articles annotated so far, perhaps helping to determine what types of articles should be chosen to be annotated in the future. First, we apply a general categorization of the research topics in the studies annotated to date for their alignment with the action items in *Vision and Change* (AAAS, 2011). Second, we categorize the populations and scope of communities under examination in each article using Bronfenbrenner's levels of social context (1977). Finally, we evaluate whether each study incorporates research questions related to diversity, equity, inclusion, and justice (DEIJ). We use these frameworks to demonstrate that the scope of the 10 articles in the annotations feature thus far has been quite broad, with some individual articles incorporating nearly all the action items, social contexts, and DEIJ considerations in the frameworks we applied. We caution, however, that articles can make valuable contributions to biology education research regardless of how extensively they address the ideas in these frameworks. Both narrowly focused and broadly defined endeavors can be valid and important. We also note that the frameworks expose some areas of investigation that are not yet well represented among annotated articles, revealing either gaps in the selection of articles or gaps in the body of literature published in *LSE*. Both the annotations feature generally, and this commentary specifically, intend to draw attention to the need for biology education research to continue making biology accessible to all learners, while also celebrating the achievements of authors and readers of *LSE* who contribute in varied and valuable ways to the enhancement of biology teaching and learning.

ELEVATING KNOWLEDGE ABOUT EDUCATION RESEARCH AND PRACTICE

Historically, many biology education researchers have been trained in laboratory or field-based research and/or teaching. While the topics that biology educators teach are solidly in the life sciences, education research in any field is a process that draws

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heavily on social science, as the focus of education is usually people learning in social contexts. Therefore, biology education research sits at the intersection of life sciences and social sciences. Consequently, biology education researchers need to understand and apply tools that bridge both domains (Dolan, 2017). Yet approaching biology education research using methods from both life sciences and social sciences often presents challenges for scholars new to the field who may be coming from one but not the other domain of training. Thus, Dolan and colleagues created the Anatomy of an Education Study feature as a resource useful to education researchers and practitioners (Dolan *et al.*, 2018). Going forward, this feature will be known as the Annotations of *LSE* Research to showcase its purpose explicitly. The annotations are freely available from the *LSE* homepage (click on the button asking "New to Education Research? Explore the annotations of *LSE* research" on the right side of the website). New annotations will be highlighted with a brief introductory feature in the journal following their release.

In terms of the process and mission of the annotations feature, monitoring editors from *LSE* are recruited onto teams to select articles in *LSE* for annotation, work with the article authors to finalize the annotations, then publish them as separate online resources. These teams work to highlight some fundamental elements of each article, such as theoretical frameworks, experimental design, methods, analyses, interpretations, and conclusions, while also pointing out effective practices for course design and instructional techniques, with the overall aim of making the articles more accessible. Working in pairs, the annotation teams have selected papers that are current, disparate in methodologies, and reflective of perceived trends in biology education research. The set of 10 annotated articles to date illustrates how biology education researchers use approaches that parallel life science research, such as controlled experiments conducted in laboratory settings (e.g., Sana *et al.,* 2020); distinct multivariate quantitative methods from the social sciences to explore factors such as relationships between cultural components of educational settings (e.g., Estrada *et al.,* 2019; Chen *et al.,* 2020); a variety of qualitative methods to explore the richness of student and/or faculty experiences (e.g., Hanauer and Dolan, 2014; Couch *et al.,* 2015; Thompson and Jensen-Ryan, 2018); and studies that combine quantitative and qualitative research into single "mixed-methods" studies (e.g., Schinske *et al.,* 2016; Ferrare, 2019; Zagallo *et al.,* 2019; Gin *et al.,* 2021).

The specific format of the *LSE* Annotations Feature was inspired by *Science in the Classroom,* a series of articles published in *Science* and subsequently annotated for high school and college students. Drawing from the idea of learning lenses in those annotations, we developed a set of five lenses that could call out elements of the annotated articles that are important for both new and experienced investigators alike (Figure 1). For the **Background** lens, we provide resources for readers to learn more about the topics of the articles, drawing from open access sources when possible. Similarly, for the **Definitions** lens, we both define terms and cite sources for those definitions when appropriate. Because some readers of *LSE* are primarily interested in what the literature says about **Instructional practice**, we expand on how and why instructors could use pedagogical techniques mentioned in the papers. Given

FIGURE 1. Each annotation falls into one of the learning lenses. Users can click next to the annotations they wish to see, and the words in the paper associated with each lens will become highlighted. Clicking on the highlighting reveals the annotations.

that one impetus for developing this feature project was to highlight the variety of education research methods used in *LSE* papers, the **Research design** lens calls attention to especially important, interesting, and/or innovative research designs or approaches. Noting that every field of study, and even every journal, has specific writing styles, we also included a lens with **Writing tips** to point out techniques that are particularly effective.

FRAMEWORKS FOR CONSIDERING THE SCOPE OF THE *LSE* ANNOTATIONS

Our decisions about which articles to annotate have been driven mainly by the methods described and the questions addressed in the studies. Here, we reflect on how the initial 10 annotated articles map onto three frameworks in education research: the action items from *Vision and Change in Undergraduate Biology Education: A Call to Action* (AAAS, 2011), the nested levels of social analysis conceptualized initially by Bronfenbrenner as microsystems, mesosystems, and macrosystems (1977), and the more recent emergence of a possible explicit focus on DEIJ (NASEM, 2023). These three frameworks help us explore various characteristics of the papers that have been chosen for the annotations so far, while also motivating future choices toward the goals to reform biology education to be more student-centered, evidence-based, and equitable.

Vision and Change Action Items

The *Vision and Change* initiative, launched in 2006, was a response to notable disconnects between the content taught in biology courses and the skills needed for scientific thinking and research. Hundreds of faculty members, administrators, and students met between 2009 and 2011 to outline specific issues and devise new approaches to aligning the science being taught with the science being done. The product of their discussions was a consensus on how to ensure that the excitement of real

research and discovery reaches and welcomes undergraduates from all backgrounds and educational environments into the field of biology. Grounded in concepts and competencies, *Vision and Change* contends that students should emerge from college with fundamental knowledge in five core concepts (content areas) and six core competencies (skill sets; AAAS, 2011).

To encourage follow-up on incorporating these core concepts and competencies in biology education, *Vision and Change* leaders also developed four action items: Integrate Core Concepts and Competencies throughout the Curriculum; Focus on Student-Centered Learning; Promote a Campus-wide Commitment to Change; and Engage the Biology Community in the Implementation of Change (AAAS, 2011). We used these four action items to categorize the annotated articles, thereby outlining the approaches through which education researchers are identifying best practices for catalyzing reforms in biology education. Given that *LSE* includes publications that consider K–12, undergraduate, graduate, postdoctoral, and faculty learners, as well as public education partnerships, we adapted the *Vision and Change* action items to fit this spectrum of students and programs beyond undergraduate initiatives.

Levels of Social Context – Micro, Meso, and Macro

Biology education research often explores the social interactions and material experiences that encourage individuals to study, achieve, conduct research, teach, and serve in the biology community. Dispositions such as science identity, self-efficacy in research, and commitment to science are grounded in social psychology, addressing individual students in social contexts such as mentor–mentee relationships, biology-related classes, research teams, campus cultures, and professional societies. As individuals seek to become scientists, they both affect and are affected by the environment around them, at levels spanning from immediate contexts, such as classrooms and laboratories, to broad structures, such as a department, an institution, or even scientific societies. It stands to reason, then, that social science research in biology education is conducted at different levels of social interactions. One theoretical framework for understanding human development through different levels of social contexts is the ecological theory of Uri Bronfenbrenner (1977). We used three of the original levels of analysis to categorize the education research articles that have been annotated for *LSE* to date.

Bronfenbrenner's ecological theory of human development was conceived initially as a strategy to balance the rigor of experimentation in psychology that occurs in highly controlled, perhaps artificial, situations with the authenticity of more natural observational approaches to understanding human maturation (Bronfenbrenner, 1977). Fundamental to this theory is considering a person as embedded in a broader ecological context, including microsystems as immediate settings and activities, mesosystems as interrelations between settings, and macrosystems as societal functions, for example, laws, regulations, rules, politics, etc.

This framework applies to education research, because individual students or teachers, schools, school systems, communities, socioeconomic factors, political systems, and cultural values, norms, and practices all contribute to outcomes (Lenhoff *et al.,* 2022). Here, we define micro level as interpersonal interactions, meso level as relationships in a unit or organization, and macro as practices or ideologies in educational systems or disciplinary fields (Ray, 2019). While most *LSE* articles do not explicitly acknowledge these levels, they are nonetheless implied in the work and/or its stated applications.

Diversity, Equity, Inclusion, and Justice (DEIJ) in Biology Education Research

Vision and Change emphasizes biology education for all students, both implicitly and explicitly indicating that the core concepts, competencies, and pedagogical approaches needed to revolutionize biology education should be accessible to students from all backgrounds and in a wide variety of educational contexts. Most efforts to enhance access to education center on the benefits of harnessing the talent, perspectives, and innovation that emerge from a workforce that reflects the demographic make-up of the society it serves (NASEM, 2023). Because of the dramatic disparities in educational opportunities, healthcare, and upward mobility that exist in the USA, and the fact that these disparities are associated with demographic identities and geographic localities, we considered whether the annotated articles speark to issues of diversity, equity, inclusion, and Justice (DEIJ). Articles were considered to include DEIJ if the work investigated inequities toward a population or subgroup of concern, if the variables of interest explicitly addressed demographic groups considered to be underrepresented in STEM fields, and/or if the theoretical framework, context, or discussion of the work very clearly emphasized DEIJ.

SCOPE OF ARTICLES ANNOTATED TO DATE

Table 1 visualizes how the first 10 annotated articles incorporate elements of the three frameworks introduced above. With the distinct framework elements as rows, a column for each article indicates whether that article was viewed to include (✓) or not include (–) each element. We based our categorization on the content of the articles, not on interpretations or applications that could be extrapolated from them. Emergent from Table 1 is the idea that some studies engage in broad coverage of almost all the elements of the frameworks, whereas others are narrower in focus. For example, Zagallo *et al.* (2019) and Gin *et al.* (2021) addressed seven of the eight framework concepts, whereas Chen *et al.* (2020) and Sana *et al.* (2020) addressed only four of the eight. More common framework elements also became clear, compared with less common elements. For example, all 10 articles focused in some way on the *Vision and Change* action item related to student-centered learning, whereas three of the 10 incorporated the action item on campus-wide commitment to change. Only four of the 10 addressed DEIJ. These gaps suggest areas that could be addressed in future choices of articles to annotate.

Notably, the presence or absence of these elements within each article is not a measure of validity, quality, or impact of the individual article. It is merely a tool to examine the breadth and depth of each study when considering these frameworks. Similarly, whether or not this set of articles fully addresses each framework element is not a value judgment on the priorities or choices of the investigators, but rather prompts a reflection on more common considerations as opposed to areas of research focus that could perhaps be more challenging to address.

TABLE 1. Frameworks for Considering the Scope of the *LSE* Annotations. Each of the annotated articles was mapped onto three frameworks: The four Action Items in Vision and Change: A Call to Action, three of Bronfenbrenner's different ecological levels of social context (micro, meso, and macro), and whether the article addressed issues of diversity, equity, inclusion, and justice (DEIJ). (✓) denotes that the article was viewed to include that element. (–) denotes that the article was viewed as not addressing that element

		1. Zagallo *et al.*, 2019	2. Gin *et al.*, 2021	3. Schinske *et al.*, 2016	4. Thompson and Jensen-Ryan, 2018	5. Couch *et al.*, 2015	6. Ferrare, 2019	7. Hanauer and Dolan, 2014	8. Estrada *et al.*, 2019	9.Sana *et al.*, 2020	10. Chen *et al.* 2020	Frequency
Vision and Change Action Items	1. Integrate Core Concepts and Competencies throughout the Curriculum	✓	–	✓	–	✓	✓	–	–	✓	–	5/10
	2. Focus on Student-centered Learning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10/10
	3. Promote a Campus-wide Commitment to Change	✓	✓	–	✓	–	–	–	–	–	–	3/10
	4. Engage the Biology Community in the Implementation of Change	✓	✓	✓	–	✓	✓	✓	–	–	–	6/10
Levels of Social Context	Micro (individual students or instructors, and their interactions)	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	9/10
	Meso (within one institution or between institutions)	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	9/10
	Macro (educational systems or disciplinary fields)	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	9/10
DEIJ	Diversity, Equity, Justice, and Inclusion	–	✓	✓	✓	–	–	–	✓	–	–	4/10
	Frequency	7/8	7/8	6/8	6/8	6/8	5/8	5/8	5/8	4/8	4/8	

1. Zagallo, P., McCourt, J., Idsardi, R., Smith, M. K., Urban-Lurain, M., Andrews, T. C., Haudek, K., Knight, J. K., Merrill, J., Nehm, R., Prevost, L. B., Lemons, P. P. (2019). Through the Eyes of Faculty: Using Personas as a Tool for Learner-Centered Professional Development. Annotated in Russo-Tait, T., Zagallo, P., Lemons, P. P., Price, R. M. (2022). Capturing Instructor Complexity with Persona Methodology.

2. Gin, L. E., Guerrero, F. A., Brownell, S. E., Cooper, K. M. (2021). COVID-19 and Undergraduates with Disabilities: Challenges Resulting from the Rapid Transition to Online Course Delivery for Students with Disabilities in Undergraduate STEM at Large-Enrollment Institutions. Annotated in Frantz, K. J., Gin, L. E., Cooper, K. M., Coffman, C. R. (2022). Open-ended Methodologies Give Voice to Student Experiences with Accommodations during the Pandemic-related Transitions to Online Learning.

3. Schinske, J. N., Perkins, H., Snyder, A., Wyer, M. (2016). Scientist Spotlight Homework Assignments Shift Students' Stereotypes of Scientists and Enhance Science Identity in a Diverse Introductory Science Class. Annotated in Coffman, C. R. and Price, R. M. (2019). Spotlighting Diversity: An Example of a Well-tested and Effective Classroom Intervention.

4. Thompson, J. J., Jensen-Ryan, D. (2018). Becoming a "Science Person": Faculty Recognition and the Development of Cultural Capital in the Context of Undergraduate Biology Research. Annotated in Price, R. M., Thompson, J. J., Jensen-Ryan, D., Coffman, C. R. (2020). Recognizing Potential Among Diverse Undergraduates: A Qualitative Study with a Strong Theoretical Framing.

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6. Ferrare, J. J. (2019). A Multi-Institutional Analysis of Instructional Beliefs and Practices in Gateway Courses to the Sciences. Annotated in Price, R. M., Ferrare, J. J., Coffman, C. R. (2020). Mixed Methods: Comparing Modes of Instruction with Instructor Beliefs.

7. Hanauer, D. I., Dolan, E. L. (2014). The Project Ownership Survey: Measuring Differences in Scientific Inquiry Experiences. Annotated in Dolan, E. L., Price, R. M., Coffman, C. R. (2018). Developing an Instrument.

8. Estrada, M., Zhi, Q., Nwankwo, E., Gershon, R. (2019). The Influence of Social Supports on Graduate Student Persistence in Biomedical Fields. Annotated in Coffman, C. R., Estrada, M., Zhi, Q., Price, R. M. (2020). Testing a Model: Identifying Supports that Influence Science Identity and Intent to Persist.

9. Sana, F., Forrin, N. D., Sharma, M., Dubljevic, T., Ho, P., Jalil, E., Kim, J. A. (2020). Optimizing the Efficacy of Learning Objectives through Pretests. Annotated in Price, R. M., Sana, F., Coffman C. R. (2021). Investigating Learning Objectives.

10. Chen, C., Sonnert, G., Sadler, P. M., Sunbury, S. (2020). The Impact of High School Life Science Teachers' Subject Matter Knowledge and Knowledge of Student Misconceptions on Students' Learning. Annotated in Coffman, C. R., Chen, C., Frantz, K. J. (2022). Generating Empirical Evidence that Teacher Knowledge of Student Misconceptions is Important.

NEXT STEPS

While the thrust of the annotations feature is to make the design, execution, publication, and applications of biology education research more accessible (Dolan, 2017), the goals of education research are to enhance teaching and learning overall. With this in mind, the frameworks used here to categorize the annotated articles could be used to assess the scope of research published in *LSE*. A shared framework may help investigators with the design, implementation, and interpretation of biology education research endeavors, while also suggesting ways to expand research portfolios or strengthen an investigator's presence in a specific niche. The categories could also

encourage investigators to consider their own research questions as fitting into a shared list of priorities for optimizing change in biology teaching and learning. Ultimately, these considerations could serve as change agents in education science if they drive investigators to consider gaps in current knowledge on certain action items, levels of analysis, and/or learner populations.

We welcome everyone to visit Annotations of *LSE* Research frequently and share them with colleagues who might appreciate the highlights and connections made through the annotations. Congratulations to LSE for 20 years of service to a wide range of investigators and institutions, all of whom are committed to the shared goal of transforming life sciences education.

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